WHITE PAPER

Connection Oriented Ethernet vs. MPLS-TE: An Ethernet Transport Layer TCO Comparison

NETWORK STRATEGY PARTNERS

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Network Strategy Partners, LLC (NSP)

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Executive Summary

Service providers around the world have chosen Carrier Ethernet technology for next-generation transport. Ethernet is attractive because it is:

- Ubiquitous
- Cost-effective
- Compatible with IP packet networks
- Capable of supporting port speeds from 10 Mbps to 10 Gbps

Service providers also have recognized the need for traffic engineering and resource management in Carrier Ethernet transport networks. Traffic engineering optimizes the allocation of network resources, resulting in efficient network resource utilization and therefore creating significant CapEx and OpEx savings as demonstrated in two recent Network Strategy Partners' whitepapers[1].

There are debates within the industry regarding Carrier Ethernet network architecture. This paper compares the total cost of ownership (TCO) of two alternative architectures:

1. Connection Oriented Ethernet (COE) with Gridpoint's E-TERM
2. MPLS-TE

For this analysis, Provider Backbone Bridging – Traffic Engineering (PBB-TE) is the assumed COE technology used. PBB-TE is part of a developing set of IEEE standards (IEEE 802.1ah, and 802.1Qay) that uses Ethernet-switching hardware as transport elements and an out-of-band management system that establishes traffic-engineered tunnel resources and service connections for Ethernet frame-forwarding. PBB-TE also has the advantage of having standardized Ethernet OAM through the IEEE 802.1ag & ITU Y.1731 standard that supports OAM capabilities similar to SONET/SDH. This study assumes that Gridpoint's E-TERM is used as the traffic-engineering resource management system that controls the PBB-TE Ethernet transport elements.

Multiprotocol Label Switching – Traffic Engineering (MPLS-TE) is a Layer 3 routing technology that uses a series of distributed routing protocols to set up Label Switched Paths (LSPs). LSPs are used to establish traffic-engineered service resources for packet forwarding. MPLS-TE provides basic OAM capabilities for detecting connectivity using Bidirectional Forwarding Detection and for tracing paths using LSP traceroute.

Both PBB-TE and MPLS-TE are being proposed for use as an Ethernet transport resource layer for Carrier Ethernet; however, they have very different architectures and cost structures. The cost of PBB-TE systems can be lower than the cost of MPLS systems due to the MPLS-TE requirement to implement a more complex series of routing and forwarding hardware capabilities and complex resiliency frameworks. The lower cost of PBB-TE systems also stems from the PBB-TE path routing complexity associated with traffic engineering, as it is managed by an out-of-band network management system (Gridpoint E-TERM).

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[1] *An Analysis of the Financial Benefits of Traffic Engineering and Traffic Management in Carrier Ethernet Networks*: http://0299d3f.netsolhost.com/NewPages/GP1.pdf.
An Analysis of the Financial Benefits of Traffic Engineering and Traffic Management in Wholesale Carrier Ethernet Networks: http://0299d3f.netsolhost.com/NewPages/GP3.pdf.

PBB-TE also has lower operational expenses than MPLS-TE. One reason for this is that PBB-TE uses a transport paradigm similar to SONET/SDH, which is familiar to transport department technicians. Provisioning and network care procedures are similar in nature to those in a SONET/SDH network. MPLS-TE Carrier Ethernet switches are essentially IP routers; therefore, provisioning and network care procedures for MPLS-TE networks are equivalent to those of IP router networks. Routers use a distributed control plane that requires a large staff of highly skilled and more expensive engineers, while SONET/SDH equipment is relatively simpler. Consequently, operational expenses for a PBB-TE network are lower than the expenses associated with the MPLS-TE network.

This document outlines a network model that is representative of a Carrier Ethernet aggregation network. The model spans a five-year period and performs a TCO analysis that compares the costs of Connection Oriented Ethernet (PBB-TE) with Gridpoint's E-TERM and MPLS-TE architectures for a Tier 1 service provider aggregation network. The results are summarized in Figure 1.

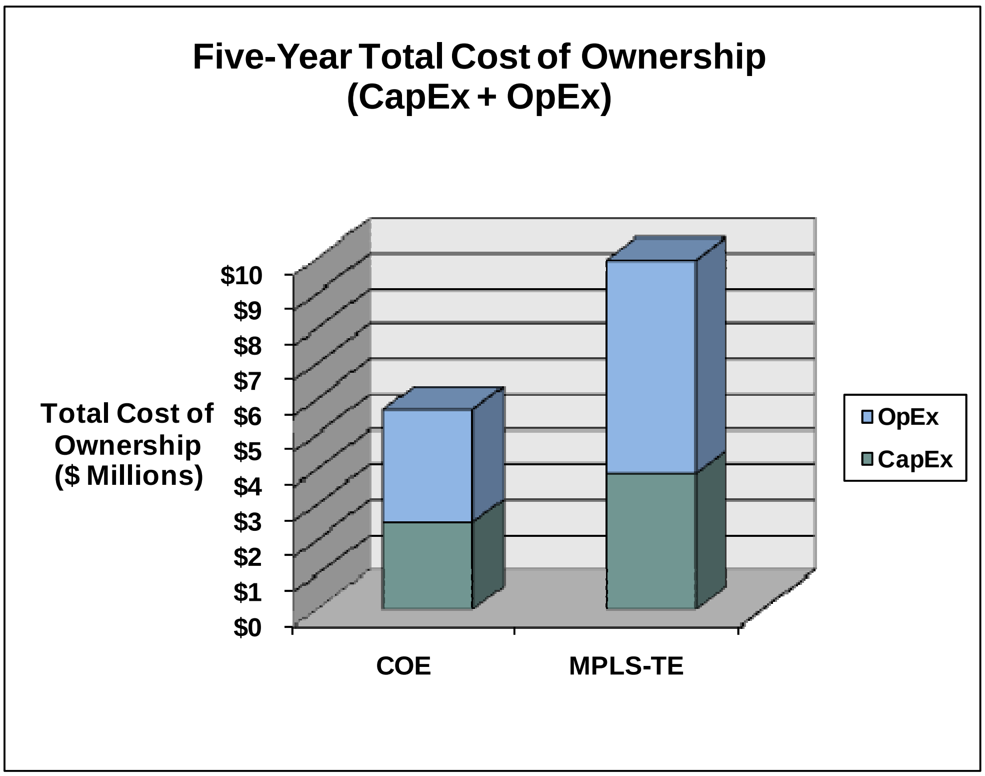


Figure 1. Comparison of the TCO of PBB-TE and MPLS-TE Over a Five-year Period

This analysis shows a 43% savings for Connection Oriented Ethernet (PBB-TE), when compared with MPLS-TE, in cumulative capital and operations expenses over a five-year period. It should be noted that most Tier 1 service providers have multiple aggregation networks in each metro area, so the numbers in this study should be multiplied by the total number of aggregation networks in the service provider's network footprint.

Introduction

For service providers to successfully and competitively deliver today's new packet-based multimedia services, a replacement for existing SONET/SDH infrastructures is required. A packet-based transport technology based on Carrier Ethernet is the choice for this new infrastructure. To get this packet-based infrastructure to provide the deterministic behavior of SONET/SDH, many service providers agree that traffic engineering and management functionality is required. However, some service providers are grappling with the question of whether to use Connection Oriented Ethernet (PBB-TE) or Multiprotocol Label Switching – Traffic Engineering (MPLS-TE) as the basis of the next-generation Carrier Ethernet transport network. This whitepaper compares the TCO of both these alternatives:

- Connection Oriented Ethernet (PBB-TE) with Gridpoint's E-TERM for traffic engineering and network resource allocation
- MPLS-TE

Provider Backbone Bridge Traffic Engineering (PBB-TE) adapts Ethernet technology to packet transport networks. It is based on layered VLAN tags and MAC-in-MAC encapsulation as defined in IEEE 802.1ah, Provider Backbone Bridging (PBB). PBB-TE, however, differs from PBB by eliminating MAC address flooding, MAC address learning, and the spanning tree protocol. PBB-TE uses a central network management system to statically update all Ethernet MAC layer forwarding tables as depicted in Figure 2. The analysis assumes that Gridpoint's E-TERM is used to control Ethernet PBB-TE Ethernet frame-forwarding and traffic engineering in the Carrier Ethernet network.

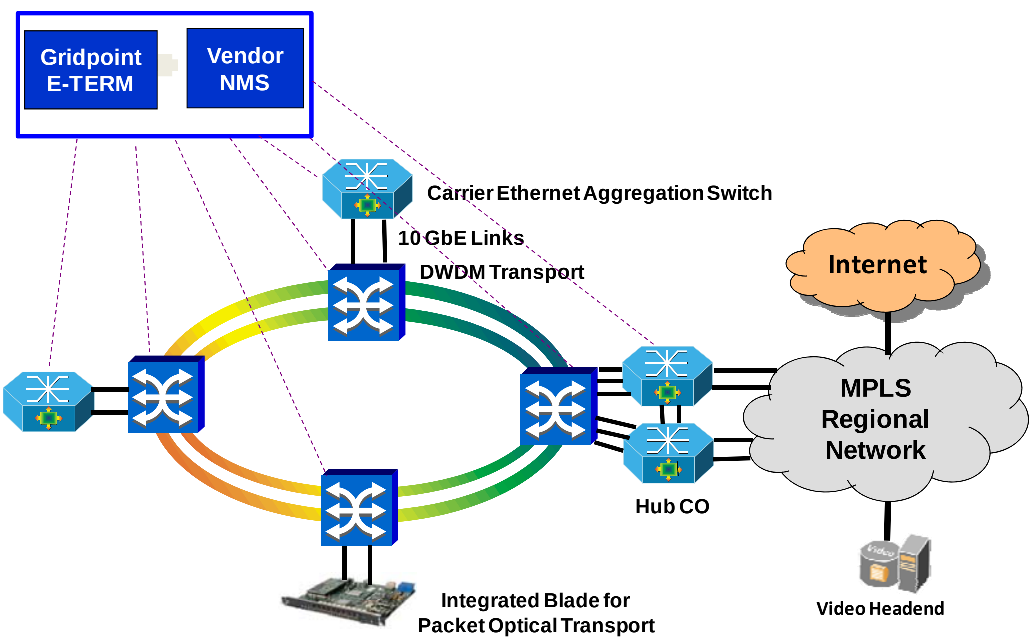


Figure 2. PBB-TE and Gridpoint E-TERM Carrier Ethernet Aggregation Network Architecture

PBB-TE's connection-oriented features, traffic engineering capabilities, and its OAM approach are inspired by SDH/SONET. Compared to Ethernet predecessor's technologies, PBB-TE has been designed to behave more predictably, and its behavior can be more easily managed and defined by the network operator. PBB-TE also implements transport path monitoring and control using operational, administration, and maintenance frames (OAM) based on the IEEE 802.1ag and augmented by the ITU Y.1731 standard. PBB-TE can also provide path protection capabilities similar to the 1:1 unidirectional protection in SDH/SONET networks. As such, PBB-TE is designed to integrate with service provider transport processes and OSS systems.

MPLS-TE provides a mechanism to create traffic-engineered connection-oriented paths, named Label Switched Paths (LSPs), between IP routers. Before a path can be calculated, a view of the network resources is determined using Layer 3 routing protocols, such as Open Shortest Path First (OSPF) or Intermediate System to Intermediate System (IS-IS), with traffic engineering extensions (see Figure 3). Based on this network view, a path is selected for an LSP using Constrained Short Path First (CSPF) algorithm, fulfilling several constraints (bandwidth, end-to-end delay, number of links traversed, etc.) simultaneously. Once the path has been calculated, the path is signaled using RSVP-TE or CR-LDP.

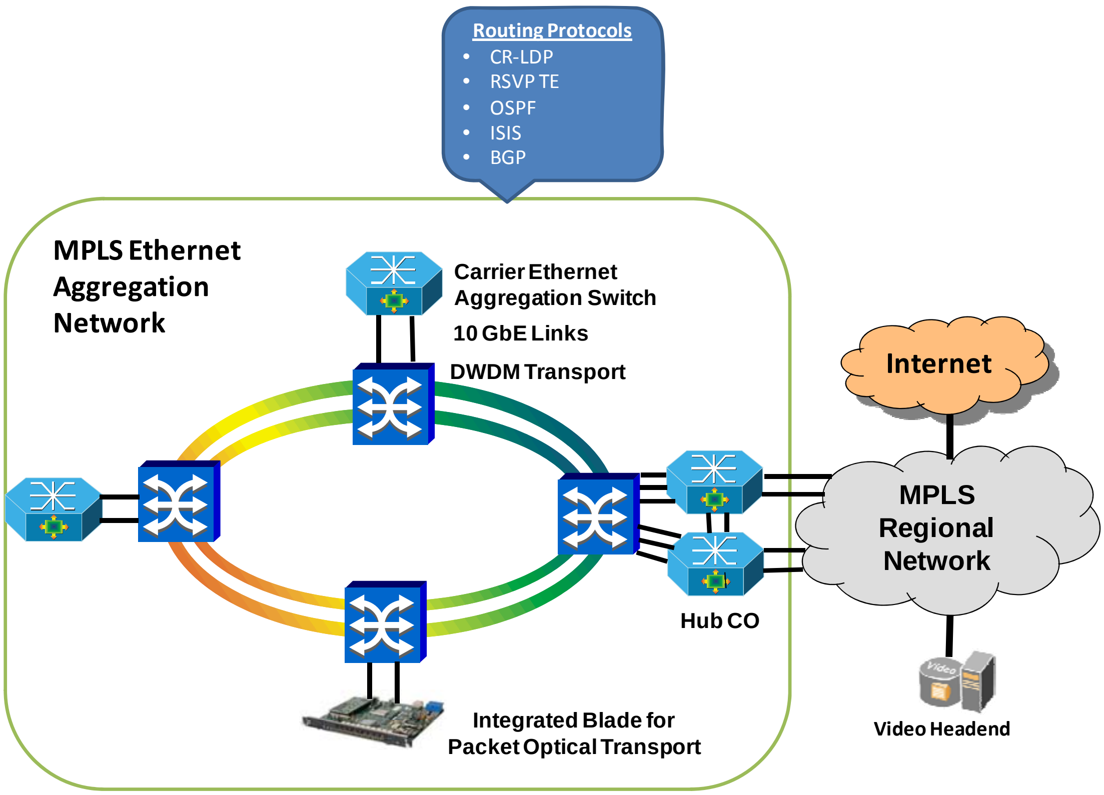


Figure 3. MPLS-TE Carrier Ethernet Aggregation Network Architecture

Given its distributed nature, the MPLS-TE is a complex technology to deploy and maintain within a network. While it is a good approach for engineering core IP routing networks, it is not the optimal technology for designing Carrier Ethernet Metro access/aggregation networks. The Metro access/aggregation network is responsible for backhauling Ethernet traffic from the access to the metro core or core network. This network should provide cost-effective transport that fits into a service provider's transport paradigm. A Connection Oriented Ethernet (PBB-TE) enabled architecture using the Gridpoint E-TERM is a more cost-effective approach to building the Ethernet aggregation network for two main reasons:

- PBB-TE switching systems leverages existing Ethernet switching technology with a lower cost structure than MPLS-TE routing/switching hardware
- PBB-TE is similar to SDH/SONET and therefore simpler and less expensive to operate than an MPLS-TE IP routing network

The following sections of this paper present the assumptions and the TCO model results and explain why Connection Oriented Ethernet (PBB-TE) with Gridpoint's E-TERM is a more cost-effective solution than MPLS-TE.

TCO Model Framework and Assumptions

The TCO model compares the capital and operational expenses for two Carrier Ethernet alternative architectures:

1. Connection Oriented Ethernet (PBB-TE) with the Gridpoint E-TERM
2. MPLS-TE

This model uses a wholesale Carrier Ethernet demand model to estimate network traffic and bandwidth requirements used for system configurations. The details regarding the network architecture and service assumptions used in the TCO model are described in the following sections.

Network Architecture Assumptions

The TCO analysis models a hypothetical Carrier Ethernet aggregation network for a Tier 1 service provider. The analysis models a single aggregation ring in a metro area as represented in Figure 4. This network is a dense wavelength division multiplexing (DWDM) ring that interconnects two large central offices (COs), three medium COs, and three small COs.

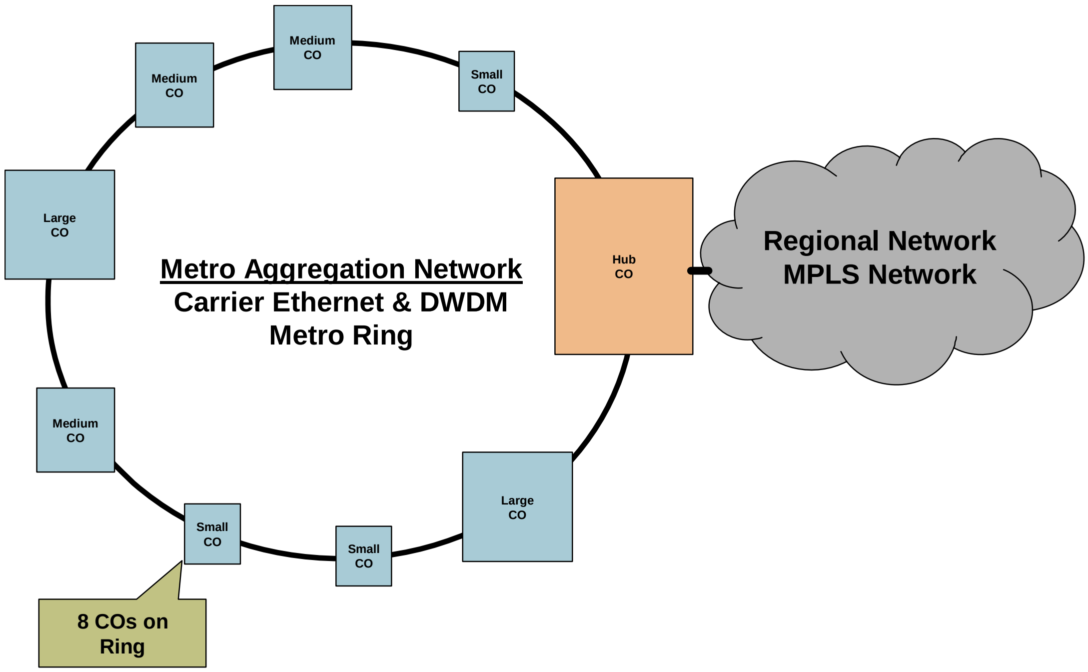
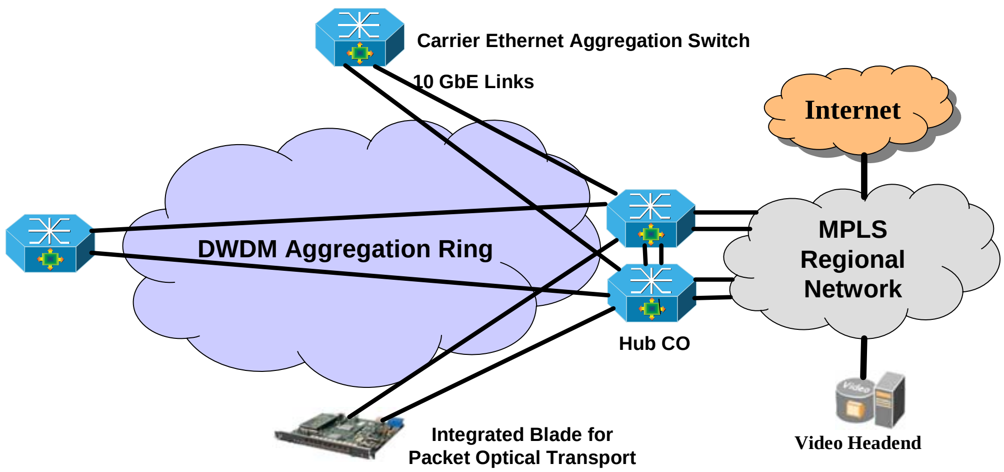


Figure 4. Tier 1 Service Provider Metro Aggregation Ring Consisting of Small, Medium, and Large COs

The architecture and physical topology of the Carrier Ethernet aggregation ring is specified in Figure 2. A DWDM metro aggregation ring combined with Carrier Ethernet switching infrastructure is used for packet transport. For large and medium COs, a standalone switch provides 1 GbE interfaces to CO equipment and connects to the DWDM transport using 10 GbE. For small COs, a Carrier Ethernet blade is integrated into the DWDM transport and provides 1 GbE interfaces to CO equipment.

The logical Carrier Ethernet network is represented in Figure 5. Ethernet switches and blades are connected to the Hub CO using a 10-GbE hub and spoke topology over the DWDM ring. The Hub CO is the point of interconnection with the regional MPLS routing network and IP service edge routers. The analysis focuses on comparing PBB-TE with MPLS-TE in the aggregation network. The assumption is that the core regional network uses large carrier class IP routers running MPLS.



Carrier Ethernet Aggregation Network Logical Topology

Figure 5. Carrier Ethernet Aggregation Network Logical Topology

Carrier Ethernet Traffic Projections

Wholesale Carrier Ethernet services are used to project demand over a five-year period. Table 1 specifies projections for services at speeds of 10 Mbps, 100 Mbps, and 1 Gbps and for large, medium, and small COs.

Table 1. Projection of Wholesale Carrier Ethernet Ports and Services

Carrier Ethernet Port Distribution						
Service	**Port Speed (Mbps)**	**Year 1**	**Year 2**	**Year 3**	**Year 4**	**Year 5**
Large Central Office	10	27	30	33	37	41
	100	29	32	35	39	43
	1000	19	21	23	26	29
Medium Central Office	10	17	18	20	22	25
	100	18	20	22	25	28
	1000	8	8	8	9	10
Small Central Office	10	13	14	15	17	19
	100	16	17	18	20	22
	1000	3	3	3	4	5

Comparison between Connection Oriented Ethernet (PBB-TE) and MPLS-TE Architectures

Based on the service demand and the network connectivity defined in the previous sections, network elements are selected to populate the Carrier Ethernet aggregation network. For the Connection Oriented Ethernet (PBB-TE) alternative, a PBB-TE edge network element is used at the edge of the network. This edge equipment is based on new PBB-TE technology and, therefore, the equipment cost is higher than that of existing VLAN Ethernet edge technology. The capital costs of these devices will go down over time; however, to be conservative, higher pricing estimates are used for the duration of the TCO model analysis not only to reflect today's market reality but to also find a lower bound for the PBB-TE cost savings.

The MPLS-TE alternative uses equipment from a leading Carrier Ethernet MPLS vendor for the capital expense estimate. These cost estimates are based on current equipment pricing.

Results of the TCO Comparison

Now that the network elements and topology have been selected, a comprehensive TCO analysis calculating network capital and operations expenses over a five-year period for a hypothetical Carrier Ethernet network is performed. The five-year cumulative TCO is presented in Figure 6. The Connection Oriented Ethernet (PBB-TE/Gridpoint E-TERM) solution is 43% less expensive than the MPLS-TE architecture over the five-year period.

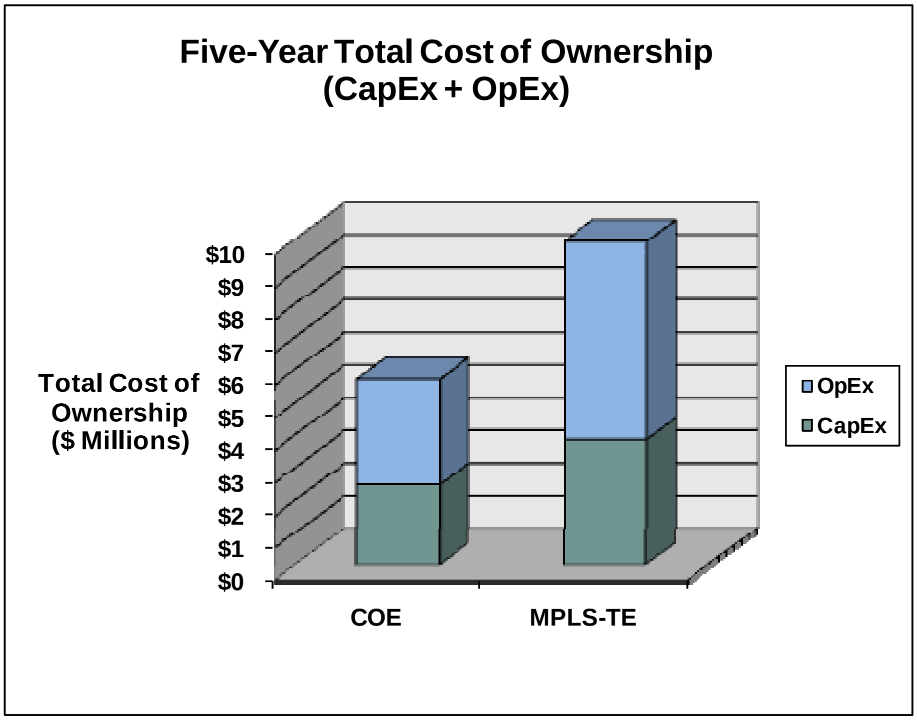


Figure 6. Five-Year Cumulative Total Cost of Ownership (CapEx + OpEx)

The cumulative capital expenses are presented in Figure 7. Network equipment is broken down by access switches, aggregation switches, and hub switches. The Connection Oriented Ethernet (PBB-TE) alternative is less capital-intensive than MPLS-TE because Layer 2 Connection Oriented Ethernet (PBB-TE) systems cost less than Layer 2.5 MPLS switches systems.

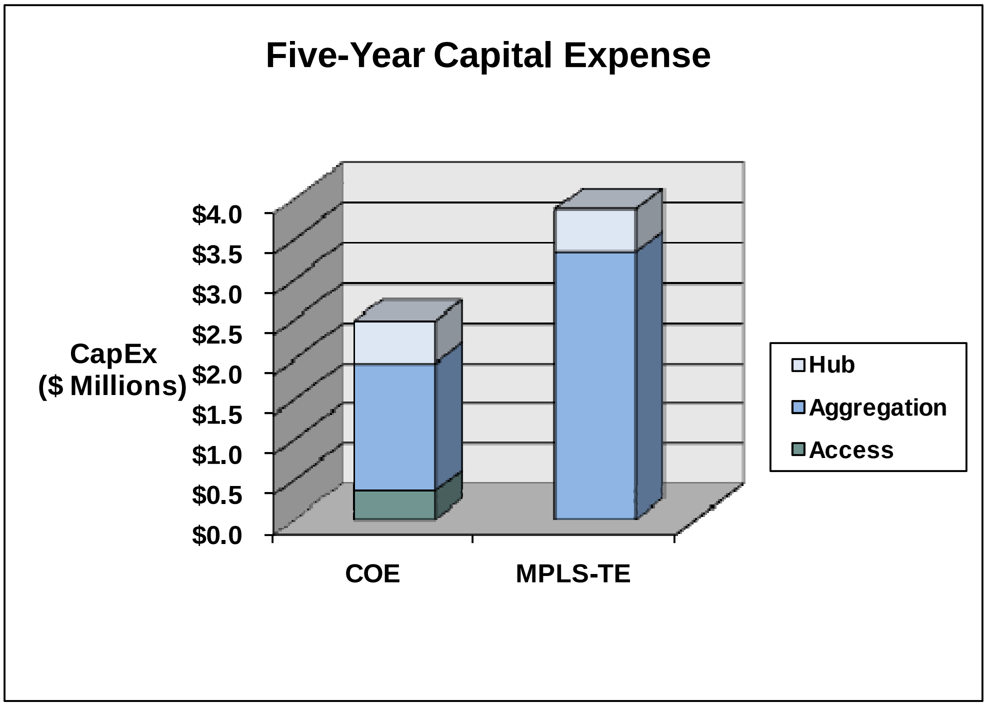


Figure 7. Five-Year Cumulative Capital Expenses

A breakdown of operations expenses over the five-year period is presented in Figure 8, and a definition of the operations expense categories is presented in Table 2. From the analysis, two primary reasons why the OpEx of the Connection Oriented Ethernet (PBB-TE/Gridpoint E-TERM) solution costs less than MPLS-TE are as follows:

1. The Connection Oriented Ethernet (PBB-TE/Gridpoint E-TERM) architecture is simpler to operate and therefore incurs lower labor costs than the MPLS-TE architecture. This is demonstrated in Figure 8 (see "Training," "Test and Certification Operations," and "Network Care").

2. Vendor service contracts are annual expenses calculated as a percentage of cumulative CapEx; MPLS-TE has higher CapEx, making its service expenses also higher than the Connection Oriented Ethernet (PBB-TE/Gridpoint E-TERM) solution. This is demonstrated in Figure 8 (see "Service Contracts" and "Sparing Costs").

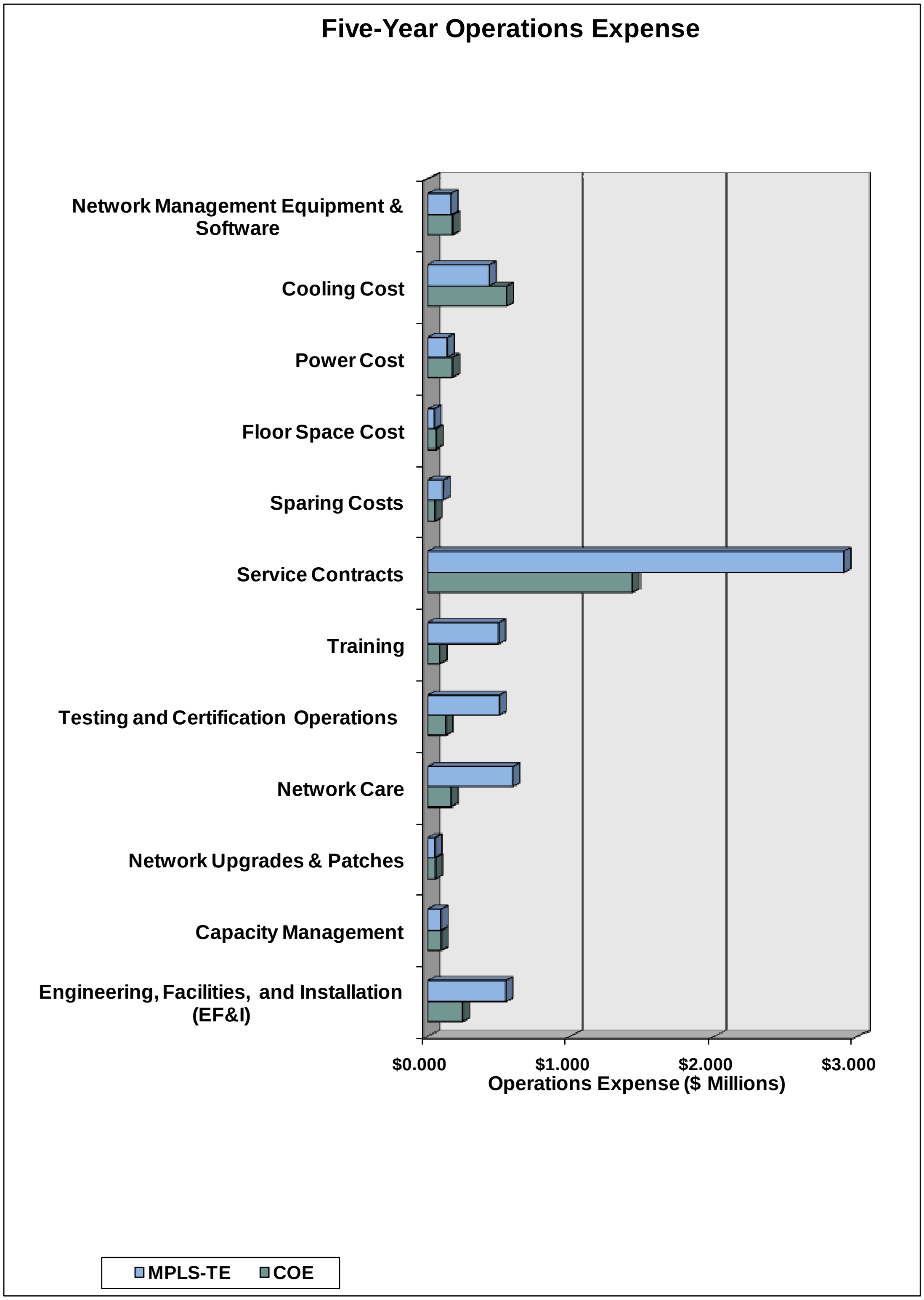


Figure 8. Five-Year Operations Expenses

Table 2. Definition of OpEx Expense Categories

Operations Expense	Definition
Engineering, Facilities, and Installation (EF&I)	This is the cost of engineering, facilities, and installation of network equipment.
Capacity Management	Capacity management is the engineering function of planning and provisioning additional network capacity.
Network Upgrades & Patches	This includes both hardware and software upgrades to the network.
Network Care	This includes network provisioning, surveillance, monitoring, data collection, maintenance, and fault isolation.
Testing and Certification Operations	Testing and certification is needed for all new hardware and software releases that go into the production network.
Testing and Certification Capital	This is capital equipment required for the test lab.
Training	Training expenses are required initially and also on an on-going basis.
Network Management Equipment and Software	This is all the hardware and software required to manage the network.
Network Transport Costs	These are the costs associated with the transport network. The calculations of these costs are described in detail in the early section on traffic forecasting.
Service Contracts	These are vendor service contracts required for ongoing support of network equipment.
Sparing Costs	These costs are associated with line card spares.
Floor Space Cost	These costs are associated with the floor space cost/square meter in the CO.
Power Cost	This is the electric utility bill to power equipment.
Cooling Cost	This is the cost of the HVAC system to cool equipment.

Conclusion

This paper presents a detailed cost comparison of two alternative approaches to building a Carrier Ethernet aggregation network with traffic engineering capabilities:

- Connection Oriented Ethernet (PBB-TE) with Gridpoint E-TERM
- MPLS-TE

The model of a representative Carrier Ethernet aggregation network over a five-year period demonstrates that the Connection Oriented Ethernet (PBB-TE/Gridpoint E-TERM) alternative is 43% less expensive than the MPLS-TE alternative. The cost savings are a direct result of lower equipment costs for Connection Oriented Ethernet (PBB-TE) and the lower operational costs of a Connection Oriented Ethernet (PBB-TE/Gridpoint E-TERM) network.

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